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Impact of Foliar Spray of NPK and Zn on Soybean for Growth, Yield, Quality, Energetics and Carbon Footprint under Dryland Condition at Indore

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ABSTRACT

Background: Dryland is characterised by drought/dry spell (s) of 10 to 15 days and is the main reason for decline in soybean production. The aim of this study was to develop a strategy of drought amelioration by using foliar sprays and enhancement of yield, quality, energetics and carbon footprint.

Methods: A field experiment was carried out at Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, College of Agriculture, Indore, (M.P.) during 2017-18 under spilt-plot design having two main plot treatments *viz.,* foliar application at dry spell (F_1), foliar application after dry spell (F_2) and seven sub plot treatments *i.e.* different variants of foliar sprays (DVFS). Different growth, yield, quality, energetic and carbon footprint traits were recorded. The data were analyzed using standard statistical procedures.

Result: The highest growth, yield, quality and energetic parameters were recorded for F_1 as compared to F_2. In case of DVFS, foliar application of water soluble complex fertilizer 19:19:19 (NPK) @ 0.5% + 0.5% $ZnSO_4$ (T_4) produced maximum values for growth, energetics, carbon footprint, oil (22.5%) and protein (43.1%) content as well as produced maximum yield.

Key words: Carbon footprint, Drought, Energetics, Foliar spray, Zinc sulphate.

INTRODUCTION

Soybean [*Glycine max* (L.) Merril] is an important oil seed and protein crop. It is considered the "Golden Bean". Madhya Pradesh is known as the "soybean state" of India, comprising 47.8% area and 48.4% of the total national production (DACFW, 2018). It ranks first amongst oilseed crops in the world and contributes nearly 25 per cent of world's total oil production (Basediya *et al.,* 2020).

Drought is a primary constraint to global crop production and global climate change is likely to increase the risk of frequent drought, especially in rain-fed and dryland agriculture. Soybean being a dominant *Kharif* season crop in India its cultivation corresponds with aberrant weather conditions especially rainfall variability. The aberrant nature of rainfall is often faced in dryland regions and reduces crop productivity because of untimely onset of and\or early withdrawal of monsoon and associated dry spell (s) at any stage in the crop season (Verma and Singh, 2017). Intermediated season *i.e.* early, mid and terminal droughts are often caused by prolonged dry spell(s) due to breaks in monsoon.

Under drought stress, reduced nutrient availability is one of the most important factors limiting plant growth. Foliar application offers numerous advantages, including satisfying the nutritional need of crop grown in moisture deficient soils in rainfed condition (Pranjit *et al.,* 2015). Foliar fertilisation provides the advantages of low application rates, homogeneous fertilizer dispersion and fast nutritional response. Hiwale (2015) advocated that the significant increment in growth, yield and quality parameters of soybean were observed due to application of KNO_3 @ 1.0% at 45 and 60 DAS. Foliar application of NPK improves the plant's capacity to synthesize, store and transport nutrients. Soybean yield and protein content rise when zinc is applied to the leaves (Kumar *et al.,* 2013). Berglund (2002) noted that foliar application of zinc at vegetative growth stage increased soybean yield. Foliar application of zinc also decreased the adverse effects of drought on seed and

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biological yield of soybean (Kobraee and Shamsi, 2011). Zinc foliar application decreased negative impact of drought and increases quantity and quality of the resulting produce (Mohammad *et al*., 2015).

Growing energy needs of making chemical fertilizers or other inputs and energy used in various agricultural operations necessitates the development of a production technology that consumes less energy input while producing more energy as output (Aakash *et al*., 2019). There is a closer relationship between energy, carbon (C) and environment, since any activities/operations in crop system needs energy in terms of inputs *i.e.* fuel, fertilizers *etc*. and every input has some carbon emission (direct or indirect) which interact with environment and determined the economic and environmental sustainability of that system (Navaz *et al*., 2017). Energy, water and carbon are important inputs in the modern agricultural production systems and, therefore, the inter-dependence of these and crop production needs to be evaluated for designing an energy, water and carbon efficient cropping system. The input-output relationship of soybean production systems varies with total biomass productivity, nutrient management and diverse tillage practices. The extreme dependence on fossil fuels (diesel) and other non-renewable energy sources and increasing emission of GHGs have shifted the focus on the judicious use of renewable energy. Thus, there is a need to assess the energy use efficiency and C-footprint of crop production systems.

The hypothesis was that the NPK and Zn have an important role in water regulation in crops. Their foliar spray may give good response under drought leading to higher crop production, varying energetics patterns and carbon footprint. Thus, the present investigation was aimed to evaluate the growth, yield, rain water use efficiency, energy use patterns and carbon footprint of seven different types of concentrations and combination of NPK and Zn applied at and after relieving of drought.

MATERIALS AND METHODS

The experiment was conducted at Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, College of Agriculture, Indore, (M.P.) during 2017-18. Experimental soil was predominantly clayey in texture, slightly alkaline in reaction (pH 7.70) and low in organic carbon (0.40%) and available nitrogen (182 kg ha^{-1}), medium in available phosphorus (14.10 kg ha^{-1}) and high in available potash (565 kg ha^{-1}).

During the crop period three dry spell of 11-15 days *i.e.* first from 28 June to 12 July 2017, second from 1 to 11 August and third from 24 September to 7 October whereas two events, of high intensity rainfall *i.e.* more than 50 mm rains in 24 hours (14 July 2017: 55.6 mm and 28 august 2017) were recorded. The third dry spell came before harvesting. Table 1 showed dates in which foliar application of fertilizers was done.

The experiment consisted of 14 treatment combinations. It was laid out in a split plot design with 3 replications. The experiment consisted of two main treatments *i.e.* foliar spray timing (FST) *viz.,* F_1: foliar application at dry spell, F_2: foliar application after dry spell and seven sub treatments *i.e.* different variants of foliar spray (DVFS) *viz.,* T_1: solution of urea 1%, T_2: solution of urea 2%, T_3: solution of water soluble complex fertilizer 19:19:19 (NPK) 0.5%, T_4: solution of water soluble complex fertilizer 19:19:19 (NPK) 0.5%+0.5% zinc sulphate ($ZnSO_4.7H_2O$), T_5: solution of 0.5% $ZnSO_4.7H_2O$, T_6: water spray and T_7: control.

Chlorophyll content was measured with "Soil and plant analysis development" (SPAD)-502 meter by punching the leaves in the eye of SPAD meter of tagged plants. The photosynthetically active radiation (PAR) intercepted was measured by canopy analyser. By holding the knob like structure direct solar radiation was determined and the transmittance solar radiation was measured by holding the lengthy tube-like structure under the plant canopy inside the experimental plot. Thus, the intercepted PAR was calculated by subtracting the transmittance solar radiation from incident solar radiation.

The energetic was determined by using standard equation (ISA, 2014). The total carbon output of the crop was computed by multiplying crop yield with an average C-content of biomass (~44% on a dry weight basis) and the total C-equivalent (C_e)/C-input was computed by multiplying the respective input used for raising the crop with their emission coefficient as per West and Marland (2002) and Lal (2004). The C-footprint of dryand soybean production system was done as per Jat *et al*. (2019).The data were analysed using Statistical Tool for Agricultural Research (STAR) software; while the significance of differences between means values were determined using Tukey's honest aignificant difference (HSD) at 1% and 5% levels.

RESULTS AND DISCUSSION

Growth parameters

Maximum plant height (52.89 cm) was recorded by F_1 (Table 2)

Table 1: Schedule of foliar application of fertilizer during the experimentation.

Dry spell		Foliar spray	Date of application	Crop stage
Occurrence	Duration			
First	15 days	1. Foliar spray during dry spell	10/07/2017	Early vegetative
		2. Foliar spray after relieving of dry spell	18/07/2017	
Second	11 days	1. Foliar spray during dry spell	09/08/2017	Flowering
		2. Foliar spray after relieving of dry spell	17/08/2017	
Third	14 days	No spray	-	Before harvesting
		No spray	-	

under FST which was 3.7% more than that for F_2. For DVFS the significantly higher plant height (55.12 cm) was noted in treatment T_2- Urea @ 2%. The increase in plant height in T_2 compared to the control was 14.8%. This might be due to the effect of nitrogen, since nitrogen increases cell division and elongation. Mona and Azab (2017) observed that the foliar application of urea increased plant height of soybean. F_1 posed its significant effect on LAI as compared to F_2 by producing index value of 3.00 (Table 2). Foliar spray during the dry spells helps in maintenance of turgor pressure of leaves which might be the resulted higher LAI. Shabbir *et al*. (2015) reported that foliar application of NPK during water stress condition increased water relation and maintained higher turgor. While in DVFS, the significantly higher value of LAI (3.18) was obtained for treatment T_4. The order of LAI under various foliar spray treatments was $T_4 > T_3 > T_2 > T_1 > T_5 > T_6 > T_7$. This result was in line with Ling and Silberbush (2002) who reported that foliar spray of NPK showed tremendous increment in leaf area.

F_1 accumulated significantly higher dry matter (20.08 g plant^{-1}) over F_2. This indicates that foliar spraying during dry spells enable plants to do their metabolic function normally, resulting in more dry matter production. Amongst DVFS, the highest dry matter (21.94 g plant^{-1}) was observed in T_4 (Table 2). This finding was supported by Haq and Mallarino (2000) who concluded that the growth parameters were significantly higher for foliar spray of NPK which results in increased total dry matter in soybean. According to Leach and Hameleers (2001) zinc is also crucial in the formation of higher dry matter. The relative growth rate (RGR) was not significantly influenced by FST, while DVFS had exerted its significant effect. Significantly superior RGR (0.0147 g g^{-1} day^{-1}) was attained by T_4. The increase in RGR over control was 13.5%, 19.7%, 23.3%, 39.4%, 9.0% and 4.1% for T_1, T_2, T_3, T_4, T_5 and T_6, respectively. This might be due to adequate supply of macro (NPK) and micro (Zn) nutrients via foliar spray which promotes faster crop growth. Gowthami *et al.* (2018) observed that application of macro and micronutrient through foliar spray increased relative growth rate as compared to control. The non-significant response of FST to RGR specified that the good rainfall occurred between 60 and 85 DAS has led to sufficient moisture in soil, thus, during these period relative crop growth rate increased at constant rate. Sharma *et al*. (2019) also reported non-significant response of foliar spray during and after drought stress.

Photosynthetically active radiation and chlorophyll content

Due to varied LAI, the PAR intercepted also differed significantly. F_1 and T_4 intercepted maximum PAR [995.6 and 1002.8 (μ mol m^{-2} s^{-1})], respectively (Table 3). The PAR intercepted by DVFS stood in the order of $T_4 > T_3 > T_2 > T_1 > T_5 > T_6 > T_7$. Significantly more PAR intercepted by F_1 and T_4 resulted from taller plant height and more leaf area index. The photosynthetic rate was significantly higher in soybean sprayed with NPK 19:19:19 @ 1.0% reported by Anjum *et al.* (2013). In this study, F_1 recorded significantly higher (37.9) SPAD values than these for F_2. This specifies that foliar application during dry spells provides nutrients quickly and helps in formation of chlorophyll. T_4 had significant more SPAD values 40.5 as compared to control. Amanmmula *et al*. (2014) observed that water soluble NPK fertilizer significantly increased the PAR interception and

Table 2: Effect of different foliar sprays and their timings on the growth attributes of soybean.

Treatments	Plant height (cm)	Leaf area index	Dry matter (g plant^{-1})	RGR (g g^{-1} day^{-1}) between 60-80 DAS
Foliar spray timing (FST)				
F_1: FS at dry spell	52.89^a	3.00^a	20.08^a	0.0125^a
F_2: FS after dry spell	51.00^b	2.65^b	18.72^b	0.0120^a
HSD (*P*≤0.05)	1.88	0.31	1.26	NS
Different variants for foliar sprays (DVFS)				
T_1: Urea @1%	51.75^{bc}	2.71^a	19.57^{bc}	0.0119^{abc}
T_2: Urea @2%	55.12^a	3.06^a	19.61^b	0.0126^{abc}
T_3: 19:19:19 (NPK) @0.5%	52.58^{abc}	3.09^a	20.1^{ab}	0.0135^{ab}
T_4: 19:19:19 (NPK) @0.5% + $ZnSO_4$ @5%	54.93^{ab}	3.18^a	21.94^a	0.0147^a
T_5: $ZnSO_4$ @5%	51.73^{bc}	2.68^a	19.02^{bc}	0.0115^{bc}
T_6: Water spray	49.53^{cd}	2.54^a	18.41^{bc}	0.0109^{bc}
T_7: Control	47.98^d	2.51^a	17.67^c	0.0105^c
HSD (*P*≤0.05)	3.20	0.48	1.18	0.0018
Source of variance				
F S timing	*	*	*	NS
DVFF	**	NS	*	**
FST × DVFF	NS	NS	NS	NS

HSD= Tukeys's honest significant difference; Significance levels: *P≤0.05; **P≤0.01; NS= Non significant; FS= Foliar spray. Differences between means with the same letter are not significant.

Table 3: Effect of different foliar sprays and their application timings on PAR, chlorophyll content, seed yield and quality parameters of soybean.

Treatments	PAR (μ mol m^{-2} s^{-1})	Chlorophyll content (SPAD)	Oil content (%)	Protein content(%)
Foliar spray timings (FST)				
F_1: FS at dry spell	995.6^a	37.9^a	22.3^a	42.6^a
F_2: FS after dry spell	980.9^b	35.7^b	22.1^b	41.9^b
HSD (P≤0.05)	13.2	1.2	0.03	0.10
Different variants of foliar sprays (DVFS)				
T_1: Urea @1%	978.3^{bc}	36.5^{ab}	22.2^b	42.5^{ab}
T_2: Urea @2%	986.4^{ab}	37.2^{ab}	22.3^{ab}	42.8^{ab}
T_3: 19:19:19 (NPK) @0.5%	991.3^{ab}	39.2^{ab}	22.4^{ab}	42.9^{ab}
T_4: 19:19:19 (NPK) @0.5% + $ZnSO_4$ @5%	1002.8^a	40.5^a	22.5^a	43.1^a
T_5: $ZnSO_4$ @5%	975.1^{bc}	35.5^{ab}	22.1^{bc}	42.3^{ab}
T_6: Water spray	955.4^c	34.5^{ab}	21.9^{bc}	41.6^{bc}
T_7: Control	943.4^c	34.0^b	21.8^c	40.7^c
HSD (P≤0.05)	18.3	6.4	0.2	1.4
Source of variance				
F S timing	*	*	*	NS
DVFF	*	*	*	*
FST × DVFF	NS	NS	NS	NS

HSD= Tukeys's honest significant difference; Significance levels: *P≤0.05; **P≤0.01; NS= Non significant; FS= Foliar spray. Differences between means with the same letter are not significant.

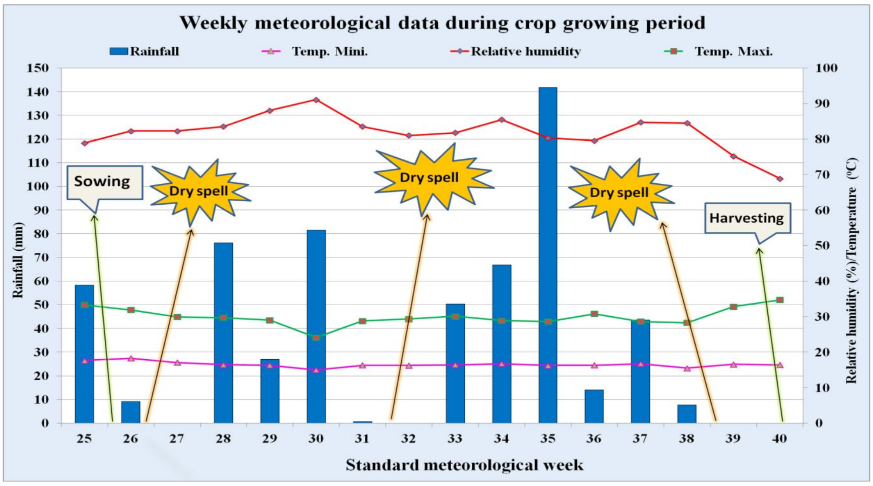

Fig 1: Weekly meteorological data during crop growing period.

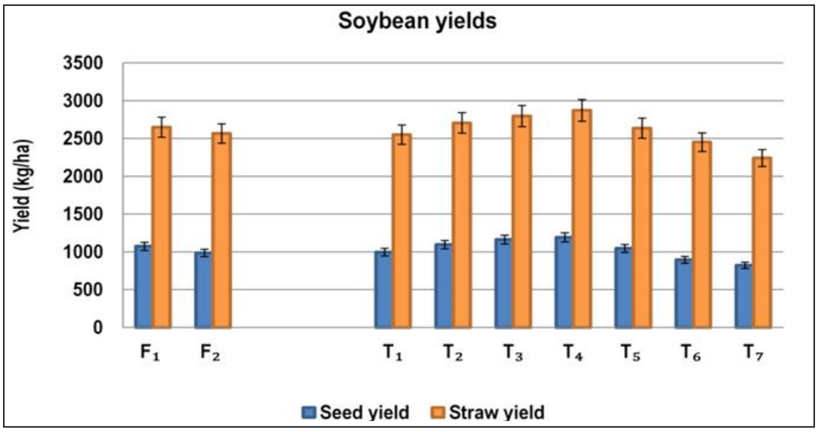

Fig 2: Effect of foliar spray and its timing on seed and straw yield of soybean.

Table 4: Effects of different foliar sprays and their application timingson energetics of soybean production.

Treatments	Input energy (MJ ha^{-1})	Output energy (MJ ha^{-1})	Net energy (MJ ha^{-1})	Energy efficiency	Energy productivity	Specific energy (MJ kg^{-1})	Energy profitability (kg MJ^{-1})	Energy intensity in economics term (MJ Rs^{-1})
Foliar spray timing (FST)								
F_1: FS at dry spell	6157	49071^{a}	42912^{a}	7.96^{a}	0.18^{a}	5.53^{b}	6.96^{a}	2.42^{a}
F_2: FS after dry spell	6157	46464^{b}	40305^{b}	7.54^{b}	0.15^{b}	6.95^{a}	6.54^{b}	2.29^{b}
HSD ($P \leq 0.05$)	NA	1056	1056	0.17	0.004	0.63	0.17	0.05
Different variants of foliar spray (DVFS)								
T_1: Urea @1%	6243	46554^{bc}	40311^{bc}	7.46^{bc}	0.16^{ab}	6.38^{ab}	6.46^{bc}	2.27^{c}
T_2: Urea @2%	6452	49965^{ab}	43513^{ab}	7.74^{bc}	0.17^{ab}	6.04^{ab}	6.74^{b}	2.43^{b}
T_3: 19:19:19 (NPK) @0.5%	6089	52094^{ab}	46004^{ab}	8.55^{a}	0.19^{a}	5.33^{b}	7.55^{a}	2.53^{ab}
T_4: 19:19:19 (NPK) @0.5% + $ZnSO_4$ @5%	6168	53440^{a}	47272^{a}	8.66^{a}	0.19^{a}	5.19^{b}	7.66^{a}	2.57^{a}
T_5: $ZnSO_4$ @5%	6112	48357^{bc}	42244^{bc}	7.91^{bc}	0.17^{ab}	6.00^{ab}	6.91^{b}	2.38^{c}
T_6: Water spray	6043	43818^{c}	37775^{c}	7.25^{c}	0.15^{ab}	6.91^{ab}	6.25^{c}	2.20^{c}
T_7: Control	6002	40144^{c}	34142^{c}	6.69^{c}	0.14^{b}	7.84^{a}	5.69^{c}	2.13^{c}
HSD ($P \leq 0.05$)	NA	2182	2182	0.35	0.04	2.07	0.35	0.10
Source of variance								
F S timing	NA	*	*	*	NS	*	*	*
DVFF	NA	*	*	*	*	*	**	*
FST × DVFF	NA	NS	NS	NS	NS	NS	NS	NS

HSD= Tukeys's honest significant difference; Significance levels: *P≤0.05; **P≤0.01; NS= Non significant; NA= Not analysis; FS= Foliar spray. Differences between means with the same letter are not significant.

net photosynthetic rate because of higher chlorophyll production and leaf area.

Seed yield

Different foliar spray treatments produced varying response on plant height, LAI, dry matter accumulation that may have brought differences in seed yield. F_1 produced maximum seed yield (1075 kg ha^{-1}) compared to that for F_2. The highest seed yield was reported by T_4 (1193 kg ha^{-1}) (Fig 2) which was statistically superior to T_1, T_6 and T_7 and was similar to the other remaining treatments. T_4 produced 45% more seed yield compared to the control. F_1 and T_4 also had maximum straw yields of 2650 and 2872 kg ha^{-1}. Malik *et al.* (2015) observed that significant increase in yield was because of

Table 5: Effects of different foliar sprays and their application timings on carbon footprint of soybean production.

Treatments	Carbon input (kg C_e ha^{-1})	Carbon output (kg C_e ha^{-1})	Carbon efficiency	Carbon sustainability index	Carbon efficiency ratio
Foliar spray timing (FST)					
F_1: FS at dry spell	150.7	1639.2^a	10.87^a	9.87^a	3.32^a
F_2: FS after dry spell	150.7	1563.8^a	10.37^a	9.37^a	2.70^a
HSD ($P \leq 0.05$)	NA	NS	NS	NS	NS
Different variants of foliar spray (DVFS)					
T_1: Urea @1%	148.5	1561.5^{abc}	10.51^{ab}	9.51^{ab}	2.96^{bc}
T_2: Urea @2%	153.0	1673.8^{ab}	10.94^{ab}	9.94^{ab}	3.16^{ab}
T_3: 19:19:19 (NPK) @0.5%	145.2	1743.5^{ab}	12.01^a	11.01^a	3.53^{ab}
T_4: 19:19:19 (NPK) @0.5% + $ZnSO_4$ @5%	160.9	1788.4^a	11.12^{ab}	10.12^{ab}	3.27^a
T_5: $ZnSO_4$ @5%	159.7	1621.1^{abc}	10.15^{ab}	9.15^{ab}	2.88^{bc}
T_6: Water spray	144.0	1473.1^{bc}	10.23^{ab}	9.23^{ab}	2.73^{bc}
T_7: Control	143.6	1349.1^c	9.40^b	8.40^b	2.53^c
HSD ($P \leq 0.05$)	NA	201.2	1.31	1.29	0.52
Source of variance					
F S timing	NA	NS	NS	NS	NS
DVFF	NA	**	*	*	*
FST × DVFF	NA	NS	NS	NS	*

HSD= Tukeys's honest significant difference; Significance levels: *P≤0.05; **P≤0.01; NS= Non significant; NA= Not analysis; FS= Foliar spray. Differences between means with the same letter are not significant.

Table 6: Effects of different foliar spray and their application timings on economics of soybean.

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C
Foliar spray timing (FST)				
F_1: FS at dry spell	20218	32253^a	12034^a	1.60
F_2: FS after dry spell	20218	29600^a	9381^a	1.46
HSD ($P \leq 0.05$)	NA	NS	NS	NA
Different variants of foliar spray (DVFS)				
T_1: Urea @1%	20494	29900^{abc}	9406^{abc}	1.46
T_2: Urea @2%	20539	32915^{ab}	12376^{abc}	1.60
T_3: 19:19:19 (NPK) @0.5%	20625	34946^a	14321^{ab}	1.69
T_4: 19:19:19 @0.5% + $ZnSO_4$ @5%	20782	35790^a	15008^a	1.72
T_5: $ZnSO_4$ @5%	20306	31398^{abc}	11092^{abc}	1.55
T_6: Water spray	19921	26852^{bc}	6931^{bc}	1.35
T_7: Control	18865	24685^c	5820^c	1.31
HSD ($P \leq 0.05$)	NA	7741.73	7680.5	NA
Source of variance				
F S timing	NA	NS	NS	NA
DVFF	NA	**	**	NA
FST × DVFF	NA	NS	NS	NA

HSD= Tukeys's honest significant difference; Significance levels: *P≤0.05; **P≤0.01; NS= Non significant; NA= Not analysis; FS= Foliar spray. Differences between means with the same letter are not significant.

application of zinc + urea compared to the control. Mannan (2014) also stated that highest values for seed and straw yields were recorded for the NPK and Mg sprays during drought. Choudhary *et al.* (2014) discovered that foliar Zn spraying increased seed yield.

Protein and oil content

Variation in seed yield under different treatments also produced significant differences in oil and protein content (Table 3). F_1 recorded significantly higher oil and protein content than these for F_2. T_4 yielded significantly more oil as compared to T_6 and T_7. Maximum protein content noticed by T_4 (43.1%) and minimum by T_7. Increase in protein content might be due to zinc which is important structural element of protein synthesizing enzymes (Ravi *et al.*, 2008). Zambre *et al.* (2017) found that foliar spray of zinc enhances the level of soluble protein and oil content under water limited conditions and also mitigated adverse effect of dry spell.

Energetics

Maximum energy input was observed in T_2 (6452 MJ ha^{-1}) because nitrogen production has huge energy requirements, while T_7 (control) recorded the lowest energy input consumption (Table 4) since it does not use any special treatment/input material. All the energetic parameters were significantly influenced by FST and DVFS. The highest output energy was received from T_4 (53440 MJ ha^{-1}) measure as seed yield. Similarly, maximum net energy was also recorded by T_4 (47272 MJ ha^{-1}) because it has less input demand and more output energy. Likewise, the energy efficiency, energy productivity and energy intensity in economic terms were significantly higher in T_4, however, the specific energy was significantly higher in T_7 (7.84 MJ kg^{-1}). Energetics findings of this study are similar to those of Navaz *et al.* (2017).

Carbon footprint

Carbon is a main integral part of the agriculture production system. C-budgeting of FST did not differ significantly (Table 5). The maximum and minimum C-inputs were consumed by T_4 (160.9 kg C_e ha^{-1}) and T_7 (140.6 kg C_e ha^{-1}). The chemical fertilizers accounted for more amount of C-share (Jat *et al.*, 2019). It might the reason that T_4 and T_7 have maximum and minimum C-input consumption. Maximum C-output was produced by treatment T_4 (1788.4 kg C_e ha^{-1}). The trend followed for C-output was $T_4>T_3>T_2>T_5>T_1>T_6>T_7$. Kumar *et al.* (2020) observed that more biomass production was the prime reason for maximum C-output. We also observed similar results in the present study. T_3 had the highest C-efficiency (12.01) followed by T_4. The sustainability of agricultural production systems mainly depends on their C-footprints. The C-footprints of soybean production system is highly dependent on ability of the crop to convert the nutrients into grains. The treatment T_3 recorded high carbon sustainability index value (CSI) (11.01) whereas the lowest CSI was observed in T_7. Similarly, T_3 had more carbon efficiency ratio (CER) compared to other treatments. This might be due to good yield and low C-input consumption under T_3. These results from the present experimentation are in close agreement to those reported by Rakesh (2020).

Economics

FST were recorded equal cost *i.e.* Rs 20218 ha^{-1} while in DVFF; the maximum cost (Rs 20782 ha^{-1}) was recorded by T_4 followed by T_3 (Rs 20625 ha^{-1}). T_4 achieved maximum gross income (Rs 35790 ha^{-1}) and net income (Rs 15008 ha^{-1}) (Table 6). Singh *et al.* (2018) reported that foliar application of water soluble fertilizer 19:19:19 (NPK) @ 2% in soybean gain maximum net returns. Table 6 again confirmed that F_1 and T_4 fetched highest values of B:C ratio *i.e.* 1.60 and 1.72 respectively.

CONCLUSION

This study showed that foliar spray of water-soluble complex fertilizer 19:19:19 (NPK) @0.5% + 0.5% $ZnSO_4$ at dry spell is a good drought mitigation technology to promote crop growth sufficiently enough. It proved sound for growth, yield, quality, energy and carbon footprint beneficial to dryland farmers.

REFERENCES

Aakash, Lalita, B., Thakur, N.S., Kirar, S.K. and Choudhary, S.K. (2019). Energetics of maize production system as influenced by varieties and nitrogen scheduling. J. Experimental Bio. Agricultural Sci. 7(5): 462-467. DOI: 10.18006/2019. 7(5).462.467.

Amanmmula, D., Sinha, K.K. and Sharma, R.P. (2014). Effect of organic manure, NPK and boron application on the productivity of wheat in sandy loam soil of north Bihar. Indian J. Pulses Res. 17: 42-44.

Anjum, S.A., Ehsanullah, L., Wang, L., Saleem, M.F. and Huang, C. (2013). Exogenous benzoic acid (BZA) treatment can induce drought tolerance in soybean plants by improving gas-exchange and chlorophyll contents. Australian J. Crop Sci. 20: 555-560.

Basediya, P., Kumar, P., Gupta, R., Bhargava, M.K., Singh, P. and Kushwaha, N.K. (2020). Study the effect of ridge and furrow system on soybean cultivation in Shivpuri district of M.P. Int. Arch. App. Sci. Technol. 11: 111-115.

Berglund, D.R. (2002). Soybean Production Field Guide for North Dakota and Northwestern Minnesota. Published in Cooperative and With Support from the North Dakota. Soybean Council. 136-138.

Choudhary, P., Jhajharia, A. and Kumar, R. (2014). Influence of sulphur and zinc fertilization on yield, yield components and quality traits of soybean (*Glycine* max L.). The Bioscan. 9: 137-142.

DACFW (2018). Agricultural Statistics at a Glance 2018, Government of India Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare. 115.

Gowthami, P., Rao, G.R., Rao, K.L.N. and Ahamed, L.M. (2018). Effect of foliar application of potassium, boron and zinc on quality and seed yield in soybean.Int. J. Chem. Stud. 6: 142-144.

Haq, M.U. and Mallarino, A.P. (2000). Soybean yield and nutrient composition as affected by early season foliar fertilization. J. Agron. 92: 16-24.

Hiwale, R. (2015). Effect of foliar application of potassium nitrate on yield, growth and quality of soybean [*Glycine max* (L.) Merrill]. Int. J. Agric. Sci. 7: 516-519.

ISA (2014). Agronomy Terminology, 6th Edition, Indian Society of Agronomy, New Delhi.

Jat, S.L, Parihar, C.M., Singh, A.K., Kumar, B., Choudhary M. and Nayak, H.S. (2019). Energy auditing and carbon footprint under long-term conservation agriculture based intensive maize systems with diverse inorganic nitrogen management options. Sci. Total Environ. 664: 659-668.

Kobraee, S. and Shamsi, K. (2011). Effects of Zn, Fe and Mn on soybean production. Ecol. 17: 23-28.

Kumar, R., Mishra, J.S., Rao, K.K., Mondal, S., Hazra, K.K. and Choudhary J.S. (2020). Crop rotation and tillage management options for sustainable intensification of rice-fallow agro-ecosystem in eastern India. Sci. Rep. 10: 1-15.

Kumar, V., Vaiyapuri, K., Amanullah, M.M. and Gopalswamy, G. (2013). Infiuence of foliar spray of nutrients on yield and economics of soybean. J. Bio. Sci. 13: 563-65.

Lal, R. (2004). Carbon emission from farm operations. Environ. Int. 30: 981-990.

Leach, K. and Hameleers, A. (2001). The effects of a foliar spray containing phosphorus and zinc on the development, composition and yield of forage maize. Grass and Forage Sci. 56: 311-315.

Malik, K., Kumar, S. and Sing, K.P. (2015). Effect of zinc, molybdenum and urea on growth and yield of mungbean [*Vigna radiate* (L.) Wilczek]. Adv. Res. J. Crop Improv. 6: 59-65.

Mannan, M.A. (2014). Foliar and soil fertilization effect on seed yield and protein content of soybean. Bangladesh Agron. J. 17: 67-72.

Mohammad, Z.L., Khan, I., Rashid, W.K., Asraf, S.A. and Sajid, M. (2015). Foliar application of micronutrient enhances wheat growth, yield and yield related Attributes. American J. of Plant Sci. 5: 864-869.

Mona, E. and Azab, E.I. (2017). Soybean yield and quality as affected by spraying NPK fertilizers compound with amino acids and micronutrients. Int. J. Chem. Technol. 10: 534-543.

Navaz, M., Kumar, S.,Chandrakar, D., Dameshwar and Ahmad, A. (2017). Impact of foliar spray of nutrients and seed treatment on economics and energetics of lathyrus (*Lathyrus sativus* L.) under relay cropping system. J. Pharmacognosy and Phytochemistry. 6: 1683-1686.

Pranjit, P.K., Hazarika, M., Sarma, D., Saikia, P., Pankaj Kumar, N., Rajbongshi, R., Nikhita, K., Bhattacharjee, M. and Srinivasarao, Ch. (2015). Effect of foliar application of potassium on yield, drought tolerance and rain water use efficiency of toria under rainfed upland situation of Assam. Indian J. of Dryland Agriculture Res. Develop. 30: 55-59.

Rakesh, K., Mishra, J.S., Mondal, S., Meena, R.S., Sundaram, P.K., Bhatt, B.P., Pan, R.S., Lal, R., Saurabh, K., Chandra, N., Samal, S.K., Hans, H. and Raman, R.K. (2020). Designing an ecofriendly and carbon-cum-energy efficient production system for the diverse agroecosystem of South Asia Energy. Energy. 214.

Ravi, S., Channal, H.T., Hebsur, N.S., Patil, B.N. and Dharmatti P.R. (2008). Effect of sulphur, zinc and iron nutrition on growth, yield, nutrient uptake and quality of safflower (*Carthamus tinctorius* L.). Karnataka J. Agric. Sci. 21: q 382-385.

Shabbir, A.N., Ashraf, M.Y., Waraich, E.A., Ahamad, R. and Shahbaz, M. (2015). Combined effects of drought stress and NPK foliar spray on growth, physiological processes and nutrient uptake in wheat. Pak. J. Bot. 47: 1207-1216.

Sharma, S.K., Chaudhary, K. and Kumar, M. (2019). AICRPDA-NICRA Centre Annual Report, CCS Haryana Agril. University Hisar, Haryana, pp 52.

Singh, S.K., Sharma, M., Reddy, K.R. and Venkatesh, T. (2018). Integrated application of boron and sulphur to improve quality and economic yield in potato. J. Environ. Bio. 39: 204-2010.

Verma, G.P. and Singh, Y.P. (2017). Rainfed Farming Development in Central India. Scientific Publishers, India. pp. 224.

West, T.O. and Marland, G. (2002). A synthesis of carbon sequestration, carbon emissions and net carbon flux in agriculture: comparing tillage practices in the United States. Agric Ecosystems Environ. 91: 217-232.

Zambre, P.B., Kolekar, P.T. and Ughade, S.R. (2017). Effect of foliar sprays of water soluble fertilizer, growth regulator and micronutrients on yield and quality of soybean. Int. J. Agr Sci. 13: 159-160.